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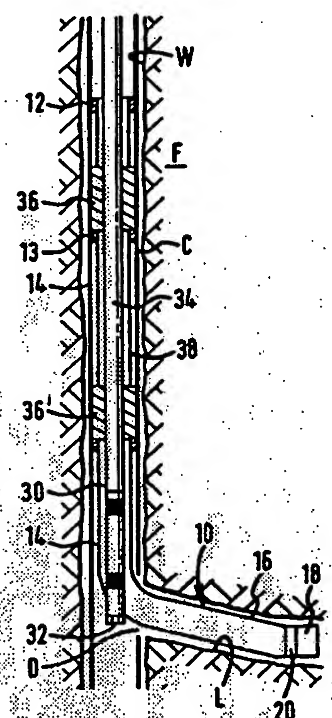
(54) Title: DRILLSTRING WITH STABILISERS FOR RE-ENTERING A PRIMARY WELLBORE

(57) Abstract

A well comprising a primary wellbore (W) and a secondary wellbore (L) leading from said primary wellbore (W) wherein a juncture is formed therebetween, said juncture lined with a tubular member (14) extending from said primary wellbore (W) into said secondary wellbore (L), characterised in that a stabiliser (36, 40) is provided for, in use, stabilising a mill milling an opening in said tubular (14) into said primary wellbore (W). A method for milling an opening in a tubular in a well of the present invention, the method comprising the step of milling an opening in said tubular member whilst being stabilised or guided by said stabiliser. The invention also provides a tubular member, a mill, a stabiliser and a system for milling an opening in a tubular in a well of the invention.



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DRILLSTRING WITH STABILISERS FOR RE-ENTERING A PRIMARY WELLBORE

This invention relates to a well comprising a primary wellbore and a secondary wellbore leading from said primary wellbore wherein a juncture is formed therebetween, said juncture lined with a tubular member extending from said primary wellbore into said secondary wellbore.

Prior to the present invention, a lateral or secondary wellbore was bored in a formation from the main or primary wellbore. The primary wellbore is usually cased and the lateral well is lined with liner. The liner may be hung using a liner hanger, from the cased primary wellbore. A packer may also be set to seal the annulus between the casing and the liner. To re-establish fluid flow through the primary wellbore, a mill is simply run through the wall of the liner to establish an opening into the primary wellbore.

A problem has been observed that the mill often mills the wrong part of the liner.

Accordingly, the invention provides a well comprising a primary wellbore and a secondary wellbore leading from said primary wellbore wherein a juncture is formed therebetween, said juncture lined with a tubular member extending from said primary wellbore into said secondary wellbore, characterised in that a stabiliser is provided for, in use, stabilising a mill milling an opening in said tubular into said primary wellbore. The stabiliser, in use, stabilises or guides a mill for milling an opening between the tubular member and said primary wellbore. The tubular member may be the top section of a liner lining the secondary wellbore, or a section of tubular linking the primary wellbore (cased or uncased) with the secondary wellbore (cased or uncased).

Preferably, said stabiliser is arranged on said

tubular member.

Advantageously, said stabiliser comprises ribs extending into said tubular member with channels arranged therebetween. The ribs are provided with flow channels therebetween to allow fluid such as mud to flow past. If the fluid flows in a direction away from the mill, the mud will be carrying swarf from the mill during the milling operation. The channels may be straight or spiralled.

Preferably, said stabiliser comprises ribs extending outwardly from said tubular member. The ribs centralising the tubular member in the primary wellbore (which may be cased).

Advantageously, said stabiliser is made from a bearing material such as zinc alloy.

Preferably, said stabiliser is hardfaced. Or may be provided with matrix milling material which may ream any casing of too small a diameter for the passge diameter required.

Advantageously, said stabiliser is integral with said tubular member. Although, the stabiliser may comprise a threaded top and a threaded bottom for attachment to said tubular member.

Preferably, said tubular member comprises at least two stabilisers.

Advantageously, said stabiliser is a tubular which has a close tolerence, such that a mill on the end of a tool string will have a close fit therewith. Preferably, said tolerence is within 0.4mm (fifteen thousandths of an inch).

Advantageously, said tubular member initially attached to said mill such that said tubular member may be lowered thereon.

Preferably, said tubular member is supported by a liner hanger. A packer to seal the annulus between a

cased primary wellbore and the tubular member may also be provided, or a metal to metal seal may be provided.

Advantageously, said mill is provided with a centring device such that said mill enters said tubular without hitting the top thereof.

Preferably, the liner comprises drift tubulars.

Advantageously, the well further comprises a bent sub connected to a lower end of the tubular member.

The invention also provides a stabiliser of of the well of the invention.

The invention also provides a tubular member provided with at least one of the invention.

The invention also provides a mill for use in the of the invention, including a first mill with an angled cutting portion on a lower end thereof for maintaining desired mill position during milling of the liner.

Preferably, the mill has an angled cutting portion comprises crushed carbide secured to the first mill.

Advantageously, the angled cutting portion is a concave shaped area at the lower end of the first mill.

Preferably, the at least one mill has a mill body with a body diameter and a lower end cutting structure extending outwardly from the mill body to a lower end diameter, and the lower end diameter is greater than the body diameter.

The invention also provides a system for milling an opening in a tubular comprising at least one stabiliser of the invention, the tubular member of the invention and the mill of the invention.

The invention also provides a method for milling an opening in a tubular in a well of the invention, the method comprising the step of milling an opening in said tubular member whilst being stabilised or guided by said stabiliser.

Certain special drift casing has a known interior diameter within a close tolerance, e.g. within forty thousandths of an inch. Also, the exterior diameter of the stabilizing member(s) is, optionally and preferably, sized within a close tolerance, e.g. fifteen thousandths of an inch. The resulting close fit between stabilizing member(s) and casing increases stiffness of the system and enhances stability of the mill(s). In one aspect special drift casing is used at such a length that it includes within it the milling assembly and the area for forming a window.

One particular mill useful in such systems has a generally cylindrical body with a flow bore therethrough from a top end to a bottom end. One or more flow ports extend laterally from the flow bore to the body's exterior. The lower end of the mill has a plurality of spaced-apart blades for milling the liner. In various aspects there are two, four, six, eight, ten, or twelve separate blades, although any suitable number is within the scope of this invention. The blades may be dressed with any suitable known matrix milling material and/or inserts by any suitable known method and in any suitable known pattern or array. In one particular aspect the blades extend downwardly with flow paths therebetween and an amount of crushed carbide is disposed within the mill partially adjacent and partially above the blades with a lower cone shape that facilitates maintenance of the mill in a desired milling position.

Preferably, a system as described above (and in detail below) is releasably secured to a liner and the entire combination is run into a wellbore so that the liner enters and lines a portion of a lateral wellbore. Any suitable known diversion device, whipstock, diverter, etc. may be located in the primary wellbore at a desired location to direct the liner into the lateral wellbore.

Following correct emplacement of the liner, the mill(s) is/are selectively released from the liner (e.g. by shearing a shearable member, stud, or pin) and the liner is milled to reestablish communication to the primary wellbore. The mill(s) and interconnected apparatuses are then removed from the wellbore. This operation can be completed in a single trip of the system into the wellbore.

Alternatively, mills and milling systems described herein may be used for any wellbore milling operation, e.g., but not limited to milling a window in a wellbore tubular, milling a fish, a packer, a whipstock, or other apparatus or structure in a wellbore. In other embodiments any mill or mill system described herein may be used in conjunction with a mill guide.

The present invention also discloses systems and methods for shrouding a main bore/lateral liner interface in areas in which formation may be exposed or unsupported.

The present invention also discloses systems and methods for installing a liner in a lateral wellbore, the liner having a preformed window located so that, upon desired emplacement of the liner, the preformed window is located above a main wellbore from which the lateral wellbore extends. In this way the preformed window, in one aspect, is positioned over a diverter or whipstock used to direct the liner into the lateral wellbore. Thus a mill is insertable and movable to and through the preformed window to mill through the diverter or whipstock, re-establishing the main wellbore.

For a better understanding of the present invention, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1A shows a side view in cross-section of a prior art primary wellbore extending down from an earth surface into a formation;

Figure 1B shows a side view in cross-section of a lateral wellbore extending from the wellbore of Figure 1A;

Figure 1C shows a side view in cross-section of an apparatus in accordance with the present installed in the primary wellbore and lateral wellbore of Figure 1B;

Figs. 1D to 1F are side views in cross-section of the primary wellbore and lateral wellbore of Figure 1C showing steps in a method of milling in accordance with the present invention;

Figure 2A is a side view in cross-section of a coupling-bushing used in the apparatus of the present invention; Figure 2B is a side view in cross-section along line 2B-2B of Figure 2A; Figure 2C shows the coupling- bushing as in Figure 2B with tungsten carbide ground smooth on exterior rib surfaces;

Figure 3A is a side view in cross-section of a the apparatus as shown in Figure 1C; Figure 3B is a side view in cross-section of a part of a second embodiment of an apparatus in accordance with the present invention;

Figure 4A is a side view of a mill in accordance with the present invention with undressed blades; Figure 4B is a bottom end view of the mill of Figure 4A; Figure 4C shows an enlargement of part of the mill as shown in Figure 4B; Figure 4D is a view in cross-section along line 4D-4D of Figure 4A; Figure 4E is a view in cross-section of the lower end of the mill of Figure 4A; Figure 4F shows an enlarged portion of the mill end shown in Figure 4E; Figure 4G is a side view in cross-section

of the mill of Figure 4A; Figs. 4H - 4I show side view of details of the lower end of the mill of Figure 4A; Figure 4J is a view in cross-section along line 4J-4J of Figure 4A;

Figure 5A and 5B are side views in cross-section of a lateral shroud system in accordance with the present invention;

Figure 6 is a side view in cross-section of a lateral shroud system in accordance with the present invention;

Figure 7 is a front view of a lateral shroud system in accordance with the present invention;

Figure 8 shows schematically a side view in cross-section steps of a method of milling in accordance with the present invention;

Figure 9 is a side view in cross-section along line 9-9 of Figure 8 of an opening made with the mill of Figure 8;

Figure 10 is a side view of a mill according to the present invention;

Figure 11 is a side view of a mill according to the present invention;

Figure 12 is a side view of a blade with a taper member in accordance with the present invention;

Figure 13 is a side view of a blade with a taper member in accordance to the present invention;

Figure 14A is a bottom view of a mill body accordance with the present invention;

Figure 14B is a bottom view of a mill body accordance with the present invention;

Figure 15A - 15D are side cross-section views of mills accordance with the present invention;

Figure 16A, 16B, and 16E are side cross-section views of a liner system according to the present invention. Figure 16C shows cross-section views along

the length of the system as illustrated in Figure 16B. Figure 16D is a cross-section view along line 16D-16D of Figure 16B. Figure 16E shows a sleeve of the system of Figure 16A installed in a wellbore.

Figure 17 is a side view partially in cross-section of a mill system according to the present invention.

Figure 18A is a side view in cross-section of a generally cylindrical mill according to the present invention. Figure 18B is a bottom end view of the mill of Figure 18A.

Figure 19 is a composite side cross-section view of steps in an operation using a system as in Figure 17. Figs. 19A - 19E are enlarged portions of Figure 19. Figure 20 is a side view in cross-section that presents an alternative embodiment of the system of Figure 17.

Referring now to Figure 1A, a main wellbore W extends down into an earth formation F and is cased with a string of casing C. Such wellbores and the drilling of them are old and well-known, as are the systems, tubulars, and methods for casing them.

Figure 1B shows the results of well-known window milling methods that have created a window D and well-known drilling methods that have produced a lateral bore L.

Figure 1C shows a liner assembly 10 according to the present invention installed in part of the main wellbore W and part extending into the lateral bore L. It is within the scope of this invention for the part of the liner assembly 10 to extend to any desired length into the lateral base L, including substantially all of the length of the lateral bore L.

A suitable support 12 holds the liner assembly 10 in place. In one aspect, the support 12 is an external casing packer, but it is within the scope of t his invention for it to be a liner hanger, tubing hanger,

pack off or any support that supports the liner assembly 10. In another aspect, a non-sealing support or supports may be used if no sealing between the exterior of the liner assembly 10 and the casing interior is desired.

A tubular liner 14 may be made from any suitable material such as metal (steel, aluminum, zinc, alloys thereof), composite, fiberglass, or plastic. Preferably, the tubular liner 14 is bendable sufficiently for a lower portion 16 to bend and enter into the lateral bore L. In one aspect a bent tubular or bent sub 18 is connected at the end of the lower portion 16 of tubular liner 14 to facilitate initial entry of the tubular liner 14 into the lateral bore L. Optional seals 13 seal the annular space between a casing 38 and tubular members 14. Optionally, an orienting apparatus 20 (including but not limited to a measurement-while-drilling device) may be used connected to the tubular liner 14 for correcting positioning and orienting of the bent sub 18 and of the tubular liner 14. Figs. 1D - 1F illustrate use of a milling system 30 to re-establish a pathway through the main wellbore W after installation of the liner assembly 10 as shown in Figure 1C. The milling assembly 30 has a mill 32 connected to a tubular string 34 (e.g. a string of drill pipe, spiral drill collars that facilitate fluid circulation, or tubing) that extends to and is rotatable from the earth surface. The wellbore W is cased with casing 38. The tubular string 34 extends movably through one or more (two shown) coupling bushings 36 (which connect together tubulars 14) (see also Figure 3B). In one aspect a spiral grooved drill collar which facilitates fluid circulation and milled cuttings removal is used between the bushings and/or thereabove; in one aspect, for thirty feet above the mill. Alternatively, a third coupling bushing and/or a fourth may be used between the two coupling bushings shown in Figs. 1D and 3B. Optionally,

a liner hanger may be connected on the top of the top coupling bushing shown in Figure 3B (in one aspect interconnected via a pup joint) to hold the tubular 14.

The milling system 30 and the tubular string 34 are movable through the tubular liner 14 and through the coupling bushings 36 so that longitudinal (up/down) movement of the milling system 30 is possible. The milling system 30 is also rotated as the tubular string is lowered so that the mill 32 contacts and begins to mill at an interior location on the tubular liner 14. In one aspect the mill 32 simply makes a ledge (in a single trip, preferably) (as in Figure 1E) in the tubular liner 34 that serves as a starting point for additional milling by another mill or mill system (not shown) that is introduced into the main wellbore W following retrieval of the milling system 30. As shown in Figure 1F, the milling system 30 may be used to mill through the tubular liner 34, re-establishing the main wellbore W and/or creating a pilot hole which provides the location for further milling by another mill or mill system.

Figs. 2A - 2C show a coupling bushing 40 usable as a coupling bushing 36 in the milling system 30. The coupling bushing 40 has internally threaded ends 41 and 42 and a series of exterior ribs 43 between which fluid can flow past the exterior of the coupling bushing 40. A series of internal slots 44 provide an internal fluid flow path through the coupling bushing 40. As desired hardfacing or tungsten carbide material 45 may be applied to outer surfaces of the ribs 43.

Figs. 4A - 4J illustrate a mill 50 usable as the mill 32 of the milling system 30. The mill 50 has a body 51 with milling matrix material 52 (and/or blades with milling inserts, not shown) applied spirally to the body 51 by known techniques. The material 52 may rough (e.g. as applied) a ground smooth. As shown in Figure 4G, a

fluid flow bore 53 extends from a top 54 of the body 51 to a bottom 55 where it communicates with an exit port 56 through the bottom 55 of the body 51. Alternatively, additional exit ports may be provided. In one aspect the inserts project beyond milling matrix material.

The lower end of the mill 50 has a ribbed member 57 with a series of downwardly projecting lower portions 58 alternating with and spaced apart from a series of blades 59. Matrix milling material 60 is placed between the blades 59 (covering mid portions 64) and over a lower end 61 of the body 51. In one aspect, as shown in Figure 4E, the matrix milling material is deposited with a ramp portion 62 to facilitate, enhance, and maintain liner engagement and/or to inhibit or prevent coring of the mill. Preferably a space 63 is left between a blade surface (or surfaces of inserts 65) and the milling matrix material 60 to provide a fluid flow course therethrough. Milling inserts 65 as desired may be applied to the blades 59.

In one aspect the coupling bushings 36 are spaced-apart about ten feet and the tubular string 34 has an outer diameter of about 4_ inches. In one aspect the coupling bushing's inner diameter is chosen so that the tubular string 34 fits tightly within, yet is rotatable within, the coupling bushings 36. In one aspect, known spiral drill pipe and/or spiral drill collars (e.g. one or more) are used adjacent and/or above the mill 32.

In one aspect the tubular liner 14 is positioned so that a lowermost coupling bushing is near the top of the window (in one aspect between two and three feet above it). In one aspect the tubular liner is installed, e.g. as in Figure 1D, and a portion of the tubular liner above the window is removed (e.g. by milling or with an internal cutter) creating a stub end in the wellbore. A coupling bushing or suitable centralizer or stabilizer is

emplaced on the stub end and then the milling system is run into the wellbore, through the newly-emplaced coupling bushing, and into the tubular liner.

Spiralled grooves may be provided in the outer surface of the coupling bushings.

Figure 5A shows a shroud system 70 for excluding earth formation 71 from an interface at a window 72 in a wellbore casing 73 between a main bore 74 and a lateral bore 75. A liner 76 has been emplaced in the lateral bore 75 and a top 77 thereof does not extend upwardly to the window 72. To prevent earth from the formation 71 from falling into the liner or the main wellbore (through the window 71), a hollow shroud 78 with a plug 79 at a bottom thereof having a ramped end 80 is inserted into the lateral bore 75 so that the ramped end 80 matingly abuts a corresponding ramped end 81 of a plug 82 in a top end of the liner 76. Optionally a plug 83 seals off the main bore 74.

In one aspect in the shroud system 70 of Figure 5A, the liner 76 is run into the lateral bore and cut at a length as shown in Figure 5A. Then the plug 82 is installed in the liner 76 and the shroud 78 is moved down into the lateral bore 75. If necessary, the shroud 78 is rotated so the ramp 80 seats correctly against the ramp 81. The liner be installed with the plug 82 in place. The plug 83 can be used with an orientation/location apparatus to insure correct positioning of the shroud 78 for entry into the lateral bore 75. Cement 84 may be installed around the shroud 78 and the liner 76. Cement 85 may be installed around the casing 73 (before or after lateral bore creation or lateral bore cementing.)

In certain aspects, the shroud 78 is made of metal (e.g. steel, zinc, bronze, and any alloys thereof), fiberglass, plastic, or composite. The shroud 78 may be solid or hollow, as may be the plugs 79 and 82.

Optionally, following shroud installation, the area in the main bore 74 adjacent the window 72 and some area above and below the window 72 is cemented with cement 86. If the shroud 78 is hollow, it is also cemented interiorly. Then, to regain access to the lateral bore 75, the cement 86 above and in the window 72 is removed or drilled out, as well as cement within the shroud 78 and the plugs 80 and 82. If the shroud 78 is solid, it is drilled through. If it is desired to re-establish flow through the main bore 74 below the window 72, the cement 86 above, adjacent and below the window 72 is removed or drilled through, as well as the plug 83. The plugs 80 and 82 may be solid or hollow.

In an alternative shroud system, rather than a plug on the lower end of the shroud entering a liner, a ring on the lower end of the shroud is positioned over the liner top and sealingly encompasses it.

Figure 8 shows a mill 90 (e.g. usable in the milling system 30, Figure 1D, as the mill 32) connected to a tubular string 91 (like the string 34, Figure 1D) in a liner 92 in a casing 93 in a wellbore 94. The mill 90 has downwardly projecting skirt 95 which defines a void area 96. The skirt 95 is dressed with tungsten carbide inserts 99 (e.g. but not limited to those disclosed in U.S. Patent 5,626,189 and pending U.S. Application Ser. No. 08/846,092 filed 5/1/97 both co-owned with the present invention and incorporated fully herein for all purposes). Roman numerals I, II, III show three different positions of the mill 90. In position I the mill 90 has not yet contacted the liner 92. In position II, the mill 90 has milled an initial ledge 97 in the liner 92. In the position III, the mill 90 has milled an opening 98 in the liner 92 (also shown in Figure 9). In position II, in one aspect, a lower coupling bushing (e.g. as in Figure 1D or 3B) close to the mill by its

contact with the string 91 inhibits the mill's tendency to deflect away from the liner 92 (i.e. to the right in Figure 8. In position III, the lower portions 95 of the mill 90 inhibit the mill from stepping off the ledge 97 and from re-entering the liner 92. The lower portions 95 facilitate movement of the mill 90 down the curve of the liner 92. A ramp portion 95a inhibits or prevents coring of the mill.

Figure 10 shows a mill 300 according to the present invention with a body 302 and a plurality of blades 304. Associated with each blade 304 is a taper member 306 which is secured to the body 302, or to the blade 304, or to both, either with an adhesive such as epoxy, with connectors such as screws, bolts, or Velcro □ straps or pieces, or by a mating fit of parts such as tongue-and-groove. The taper members may be made of any suitable wood, plastic, composite, foam, metal, ceramic or cermet. In certain embodiments the taper members are affixed to the mill so that upon contact of the lower point of the mill blades with the casing to be milled, the taper members break away so that milling is not impeded.

Figure 11 shows a mill 330 according to the present invention with a body 332 and a plurality of blades 334. A taper device 336 is secured around the mill 330 or formed integrally thereon. The taper device 336 extends around the entire circumference of the mill 330 beneath the blades 334 and facilitates movement of the mill 330 through tubulars. The taper device 336 may be a two-piece snap-on or bolt-on device and may be made of the same material as the taper member 306.

Figure 12 shows a blade-taper member combination with a blade 340 having a groove 342 and a taper member 344 with a tongue 346. The tongue 346 is received in the groove 342 to facilitate securement of the taper member 344 to the blade 340. Optionally, an epoxy or other

adhesive may be used to glue the taper member to the blade, to a mill body, or to both. The tongue and groove may be dovetail shaped.

Figure 13 shows a blade-taper member combination with a blade 350 and a taper member 352 with a recess 354. The blade 350 is received in and held in the recess 354. Optionally an adhesive may be used to enhance securement of the taper member 352 to the blade, to the mill, or to both.

Figure 14A shows a mill body 370 like the bodies of the mills shown in Figure 5A, 10, and 11, but with a series of grooves 372 therein which extend longitudinally on the mill body and are sized, configured, and disposed to receive and hold a taper member as shown in Figure 10, Figure 12, or Figure 13. Such a mill body may be used instead of or in combination with any previously-described taper securement means.

Figure 14B shows a mill body 380 like the bodies of the mills shown in Figs. 5A, 10, and 11, but with a series of dovetail grooves 382 therein which extend longitudinally on the mill body and are sized, configured, and disposed to receive and hold a taper member as shown in Figure 10, Figure 12, or Figure 13. Such a mill body may be used instead of or in combination with any previously-described taper securement means.

Figure 15A shows a mill 100 usable as the mill in any system described herein which has a cylindrical mill body 101 to which is releasably secured a circular ring 102 that tapers from top to bottom with a taper 103. Shearable pins or bolts 104 releasably hold the ring 102 to the mill body 101. The ring 102 is sized to facilitate passage of the mill 100 through a tubular member and also to inhibit undesired abutment of the mill 100 on an edge or surface of a coupling bushing, e.g. as a system as in Figure 1D is moved down through the

coupling bushings 36. Upon contact of the ring 102 with a top of a coupling bushing, the pins 104 shear and the mill 100 — which is now positioned of the top entry into the coupling bushing due to the position of the ring 102 — easily enters the coupling bushing.

Figure 15B shows a mill 110 usable as the mill in any system described herein which has a cylindrical mill body 111 to which is releasably secured a ring 112 that tapers from top to bottom with a taper 113. Shearable pins or bolts 114 releasably hold the ring 112 to the mill body 111. The ring 112 is sized to facilitate passage of the mill 110 through a tubular member and also to inhibit undesired abutment of the mill 110 on an edge or surface of a coupling bushing, e.g. as a system as in Figure 1D is moved down through the coupling bushings 36. Upon contact of the ring 112 with a top of a coupling bushing, the pins 114 shear and the mill 110 — which is now positioned of the top entry into the coupling bushing due to the position of the ring 112 — easily enters the coupling bushing.

Figure 15C shows a mill 120 usable as the mill in any system described herein which has a cylindrical mill body 121 to which is releasably secured a circular cylindrical ring 122. Shearable pins or bolts 124 releasably hold the ring 122 to the mill body 121. The ring 122 is sized to facilitate passage of the mill 120 through a tubular member and also to inhibit undesired abutment of the mill 120 on an edge or surface of a coupling bushing, e.g. as a system as in Figure 1D is moved down through the coupling bushings 36. Upon contact of the ring 122 with a top of a coupling bushing, the pins 124 shear and the mill 120 — which is now positioned of the top entry into the coupling bushing due to the position of the ring 122 — easily enters the coupling bushing. In one aspect, the rings remain in the

wellbore. In certain aspects, the rings are made of steel, brass, phenolic, composite, plastic, metal, or fiberglass.

As any of the mills shown in Figs. 15A - 15C move down into the coupling bushing and further downwardly, the rings 102, 112, and 122 remain atop a coupling bushing and the mill (and related tubulars) move through the ring.

In one aspect the rings are held with shear pins which shear in response to about 500 to 6000 pounds of force, and, in one aspect, about 4000 pounds of force. Shearing of a ring 102, 112, or 122 gives a positive indication at the surface of a precise location in the wellbore and, in certain aspects, a known location at a point above and near the area at which milling will commence.

The mills of Figs. 15A - 15D represent schematically any suitable known mill. Such a mill may be dressed with any known milling matrix material and/or milling inserts in any known array, pattern or configuration by any known application method.

The rings 102, 112, and 122 as shown completely encircle and encompass the cylindrical mill bodies with which they are associated. In certain embodiments acceptable centering of a mill is achieved by a partial ring (e.g. that encompasses about 180 degrees or about 270 degrees of the mill body's circumference) or by individual blocks whose cross-section appears like the cross-sections of the rings in Figs. 15A - 15C, but which are spaced apart around the mill body. in certain aspects two, three, four or more such blocks are used with a width, as viewed from above of between about one to about ten inches.

Figure 15D shows a mill 126 with a cylindrical mill body 125 having a lower concave face 128 having

relatively sharp corners 127. Any mill in Figs. 15A - 15D (and any mill disclosed herein) may be dressed with any known matrix milling material, rough or ground smooth; any known milling inserts in any known pattern, array, or combination; any combination thereof; and/or with milling inserts projecting out from and beyond matrix milling material.

Figure 16A shows a system 200 with a tubular member 202 having a top end 204 with an anchor 206 and a bottom end 208 with a plug, (preferably drillable) 210. An anchor may be provided at the end 208. A bar, whipstock, or diverter 212 is secured at a lower end of a pre-formed or pre-machined window 214 to and within the tubular member 202.

A sleeve 220, e.g. a liner or wellbore tubular, (made e.g. of metal, brass, bronze, zinc, zinc alloy, aluminum, aluminum alloy, fiberglass, or composite) is releasably secured in or is inserted into and through the tubular member 202. The sleeve 220 is moved down to contact the diverter 212 which urges the sleeve 212 to a position as shown in Figure 16B (e.g. into an already underreamed formation portion or into a lateral bore extending from a main wellbore.

When the sleeve 220 is in the position shown in Figure 16B an activatable sealing material 222 disposed around the edge of the window 214 is activated to effect sealing securement of the sleeve 220 at the window 214. Preferably a flange 224 formed of or secured to the sleeve 220 extends interiorly beyond the edge of the window 214 to facilitate sealing of the sleeve at the window and to serve as a stop and locking device.

Any suitable stored energy medium may be used as the sealing material 222, including, but not limited to, thermite and other iron oxide-aluminum compounds which react to form a metal seal or weld between parts and

which are activated by heat with suitable initiation devices as are well known in the art indicated schematically by the device 221, Figure 16E.

In one aspect, not shown, the sleeve 220 has an open lower end. As shown in Figs. 16A and 16B a pressure-containing drillable shoe or end cap 226 seals off the sleeve's bottom end.

In one aspect the diverter 212 is replaceable or removable in the wellbore or at the surface. The sleeve 220 may be any desired length.

As shown in Figure 16E a sleeve 240 (like the sleeve 220) with a flange 241 has been installed at a pre-formed window 244 of a tubular body 246 installed in a casing 248 of a wellbore 250 extending from an earth surface down in an earth formation 252 and sealed in place with sealing material 243. A top anchor 254 anchors the top of the tubular body 246 in casing 248. A diverter 242 secured within the body 246 (removable or not) has urged the sleeve 240 into an underreamed part of the formation 252 and a liner 256 has been inserted into and through the sleeve 240. The liner 256 (any desired length) extends down into a lateral wellbore 258. A liner hanger or packoff liner hanger 260 is at the top of the liner 256. The liner may be cemented into place with cement 262. An anchor 255 anchors the bottom of the tubular body 246. Alternatively a plug may be used instead of, or in addition to, the anchor 255.

In one aspect a system with a sleeve as shown in Figure 16A or 16E is run in a well and set, or bridged, across an already milled and under-reamed portion of casing. The sleeve is then pushed down to the diverter and forced out the pre-machined window in the tool body. In this position, the flange on the sleeve is adjacent to a shoulder in the pre-machined window and positioned in place. The stored energy medium reaction is then

initiated creating a pressure-containing seal between the flange and the tool body. At this point, a lateral open hole may be drilled or an existing lateral open hole may be lengthened. An additional length of liner may be run into the drilled open hole and hung off the sleeve and then cemented into place.

Alternatively, the lateral open hole is first drilled and then an entire liner string with a flange on top (like, e.g. the flange 241, Figure 16E) is run into place. A seal is then activated (as with the systems of Figs. 16A and 16E with sealing material 222 or 243). If desired, the liner is then cemented in place.

In another embodiment, a system as in Figs. 16A or 16E is run into a new well (without a sleeve or liner in place within the tool body) by placing the tool body directly in a new casing string while running in hole, with slight modifications (e.g. no anchors or plugs are needed) to the tool body. The aforementioned procedures are then followed, with the absence of section milling and under-reaming.

Figure 17 shows a mill system 400 according to the present invention which includes a tubular member 402 with a lower box end 404 and a flow bore 406 from a bottom end 408 to a top end 410. Stabilizers may be emplaced around a tubular 402 or the tubular 402 with stabilizers may be one piece. Three stabilizers 411, 412, 413 may be integrally formed of or the tubular 402, e.g. by welding. In one aspect the stabilizers consist of hardface material welded to the tubular body. Spiral grooves 419 extend from the top to the bottom of each stabilizer which define spiral portions 414 of each stabilizer. Optionally, these spiral portions are dressed with crushed carbide 416 or other suitable hardfacing, matrix milling material, and/or milling inserts.

A mill 420 is connected to the lower end 408 of the tubular member 402 and fluid is flowable through the flow bore 406 to and through the mill 420. In one particular specific embodiment, described here by way of illustration and not limitation, the outer diameter of the tubular member 402 is about 4.000 inches; each stabilizer 411, 412, 413 is about three feet long; each space 418 between stabilizers is about ten inches; the distance from the bottom of the stabilizer 411 to the top of the mill 420 is about four feet; the distance from the bottom end of the mill 420 to the top of the stabilizer 411 is about fifteen feet; and the distance from the bottom of the stabilizer 413 to the top end of the tubular member 402 is about twelve feet. This particular specific embodiment of a system 400 may be used with five inch special drift casing with the spiral portions 414 extending outwardly slightly beyond the 4.369 inch drift diameter limit. The spiral portions 414 will ream any portion within the casing up to the 4.375 inch size (e.g. the casing is about 4.369 inches and the stabilizer blades are at 4.375 inches).

Figs. 18A and 18B show the mill 420 with a generally cylindrical body 422 having a flow bore 424 extending from a top end 426 down to a lower exit port 428. One or more side flow ports 430 entrance the movement of cuttings and debris away from a plurality of spaced-apart milling blades 432 which are dressed with inserts 434. In the embodiment shown there are three ports 430 equally spaced around the body 422. Any suitable known inserts may be used in any suitable known pattern or array for the inserts 434 and/or matrix milling material may be used on the blades. In one aspect the blades 432 of the mill 420 at the lower end of the mill extend outwardly to a larger diameter than an upper part of the body 422a. The lowermost inserts on the blades can achieve an

aggressive point or small area contact with the tubular to be milled through. Such difference in diameter also facilitates fluid flow from the bottom of the mill upwardly.

A recess 436 in the lower part of the body 422 an amount 438 of the crushed carbide therein (e.g. welded in) whose lower surface 440 is generally cone-shaped to facilitate correct positioning of the mill on casing being cut and to urge the mill toward the parent bore once an initial cut out is achieved through the liner and urged toward the lateral at the bottom of the window creating a longer window. Thus the mill maintains its position so it cuts the lateral liner and so slipping around the bend in the lateral liner is inhibited. Spaces 442 between blades provide for fluid flow. A portion 444 of the bore 424 is shown as vertical (straight) but it may be canted with respect to the bore 424. Alternatively any of the bore configurations disclosed herein including but not limited to those in Figs. 4E and Figs. 38B-49B, may be used in the mill 420.

Figure 19 shows five steps, 1 - 5, in a milling operation according to the present invention with a system 400 as shown in Figure 17. In step 1, (see enlarged portion in Figure 19B) the system 400 has been introduced from the surface on a rotatable tubular string 450 with a stabilizer or crossover sub so that the mill 420 is approaching the beginning of a bend 452 in a liner 454 which lines a lateral wellbore 456 (see Figure 19C) extending laterally from a primary wellbore 458 cased with casing 460. The liner 454 may be made of special drift tubulars. Prior to liner installation, the whipstock is removed. The primary and lateral wellbores are shown only in Figure 19C but are present with the system as shown in Figure 19 and Figs. 19A, 19B, 19D and 19E. The liner 454 in one aspect extends to a point

above the top stabilizer 411 in the wellbore as shown in Figure 19.

In step 2 (see enlarged portion in Figure 19A) the mill 420 is lowered further and is beginning to enter the bend 452 of the liner 454 at which milling has commenced. In step 3 (see enlarged portion in Figure 19C) the mill 420 has been lowered so that the lower edge of the blades 432 contacts the liner 454 at the location of milling. The stabilizer 411 is still wholly within a straight portion of the liner 454. The top of liner 454 may be in any desired location, e.g. but not limited to between ten and two hundred feet above the window location to assist in holding the mill 420 against that portion of the liner 454 to be milled through and to prevent the mill 420 from entering the lateral wellbore 456.

In step 4 (see enlarged portion in Figure 19D) in an initial cut out the mill has broken through the outer diameter of the liner and the first stabilizer has begun to move into the bend area.

In step 5 (see enlarged portion in Figure 19E) the mill 420 has milled through the liner 454 reestablishing communication through the primary wellbore 458 from above the system 400 to below the system 400. The system 400 is then removed from the wellbore. Additional milling or reaming may be done with any suitable tool.

In certain embodiments of the particular specific embodiment of the system 400 previously described (i.e., the particular embodiment with spaces 418 about ten inches long, etc.), the distance from the bottom of the mill to the lower end of the lowest stabilizer 411 ranges between 0 and 5 feet and preferably between 0 and 4 feet; the stabilizer 413 ranges in length between 24 and 48 inches (as do the other stabilizers 411 and 412); and the length (height) of the spaces 418 ranges between 8 and 14 inches. It is preferred in certain embodiments that the

system 400 be sufficiently stiff that the lower end of the mill 420 deflects no more than about .4 inches from the axis of the system 400 and preferably no more than about .3 inches from this axis.

Figure 20 illustrates a "single-trip" modification for the system of Figure 17 (and for any system disclosed herein) with which a liner L (like the liner 454, Figure 19) is releasably suspended from the tubular 402 by a liner hanger H shear-pinned to the tubular 402 with shear pins P. The system as shown in Figure 20 (and Figure 17) is run into a wellbore so that the liner enters a desired lateral wellbore and is properly positioned. Then force is applied to the shear pins P to release the tubular 402 and mill 420. Rotation of the string to which the tubular 402 is attached (which string extends to earth surface) rotates the mill to mill the liner L.

CLAIMS:

1. A well comprising a primary wellbore (W) and a secondary wellbore (L) leading from said primary wellbore (W) wherein a juncture is formed therebetween, said juncture lined with a tubular member (14) extending from said primary wellbore (W) into said secondary wellbore (L), characterised in that a stabiliser (36,40) is provided for, in use, stabilising a mill milling an opening in said tubular (14) into said primary wellbore (W).

2. A well as claimed in Claim 1, wherein said stabiliser (36,40) is arranged on said tubular member (14).

3. A well as claimed in Claim 2, wherein said stabiliser (36,40) comprises ribs extending into said tubular member (14) with channels (44) arranged therebetween.

3. A well as claimed in Claim 2 or 3, wherein said stabiliser (36,40) comprises ribs (43) extending outwardly from said tubular member (14).

4. A well as claimed in any preceding claim, wherein said stabiliser is made from a bearing material such as zinc alloy.

5. A well as claimed in any preceding claim, wherein said stabiliser (36,40) is hardfaced.

6. A well as claimed in any preceding claim, wherein said stabiliser (36,40) is integral with said tubular member (14).

7. A well as claimed in any of claims 2 to 5, wherein said tubular member (14) comprises at least two stabilisers (36,40).

8. A well as claimed in claim 1, wherein said stabiliser is a tubular which has a close tolerence, such that a mill on the end of a tool string will have a close fit therewith.

9. A well as claimed in Claim 7, wherein said tolerence is 0.4mm (fifteen thousandths of an inch).

10. A well as claimed in any preceding claim, wherein said tubular member (14) initially attached to said mill such that said tubular member (14) may be lowered thereon.

11. A well as claimed in any preceding claim, wherein said tubular member (14) is supported by a liner hanger (12).

12. A well as claimed in any preceding claim, wherein said mill is provided with a centring device such that said mill enters said tubular without hitting the top thereof.

13. A well as claimd in any preceding claim, wherein the liner comprises drift tubulars.

14. A well as claimed in any preceding claim, further comprising a bent sub connected to a lower end of the tubular member.

15. A stabiliser of any of the preceding claims.

16. A tubular member provided with at least one stabilizer as claimed in Claim 14.

17. A mill for use in the well as claimed in any of Claims 1 to 14, including a first mill with an angled cutting portion on a lower end thereof for maintaining desired mill position during milling of the liner.

18. A mill as claimed in Claim 16, wherein the angled cutting portion comprises crushed carbide secured to the first mill.

19. A mill as claimed in Claim 15 or 16, wherein the angled cutting portion is a concave shaped area at the lower end of the first mill.

20. A mill as claimed in Claim 15, 16 or 17, wherein the at least one mill has a mill body with a body diameter and a lower end cutting structure extending outwardly from the mill body to a lower end diameter, and the lower

end diameter is greater than the body diameter.

21. A system for milling an opening in a tubular comprising at least one stabiliser of claim 15, the tubular member of claim 16 and the mill of any of claims 17 to 20.

17. A method for milling an opening in a tubular in a well as claimed in any preceding claim, the method comprising the step of milling an opening in said tubular member whilst being stabilised or guided by said stabiliser.

FIG. 1A
Prior Art

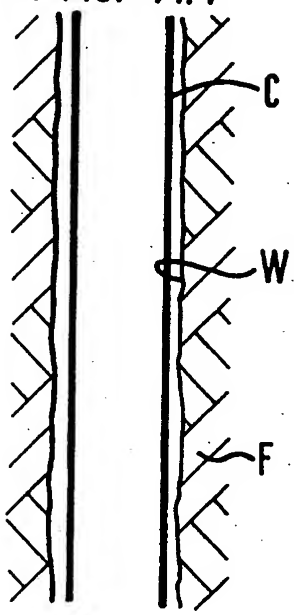


FIG. 1B
Prior Art

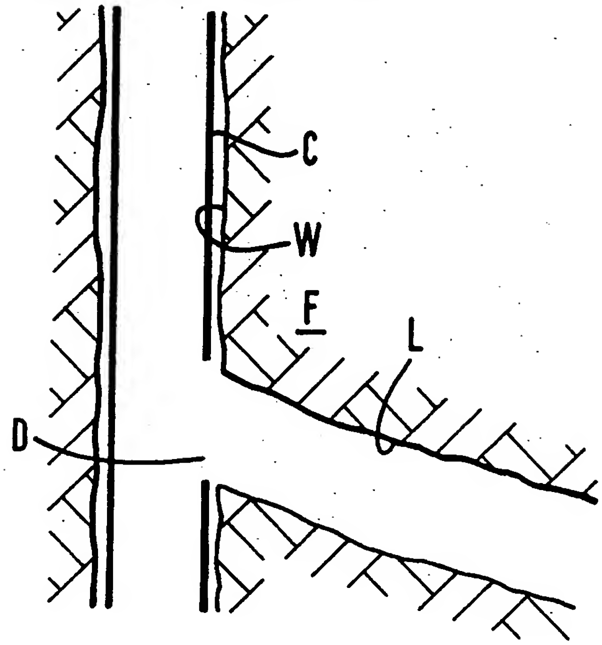


FIG. 1C

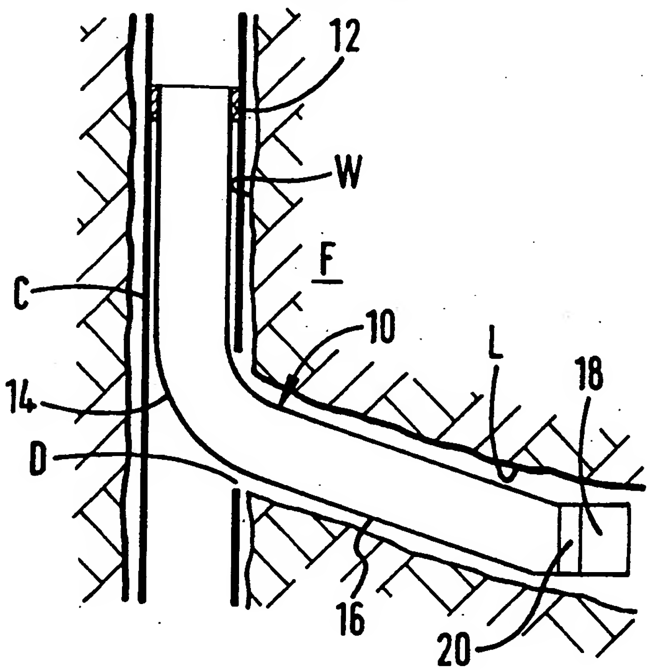


FIG. 1D

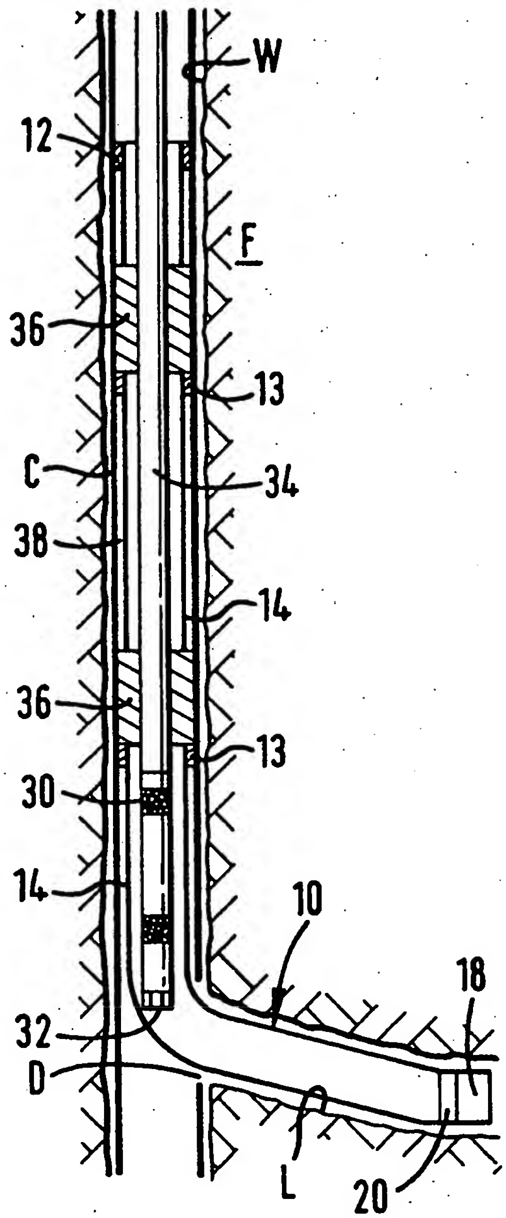

W
12
F
36
13
C
34
38
14
36
13
30
14
10
18
32
D
L
20

FIG. 1E

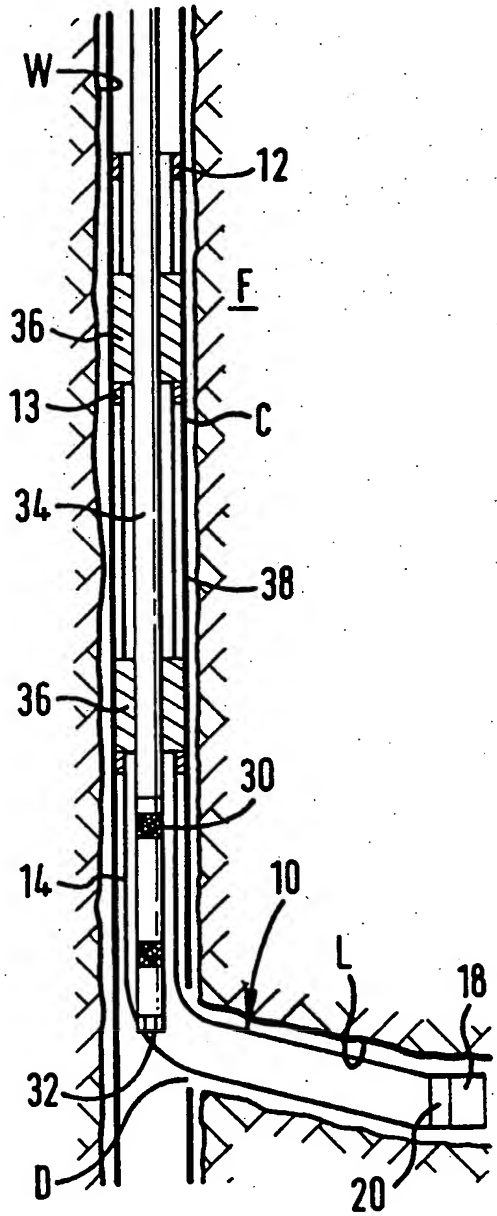
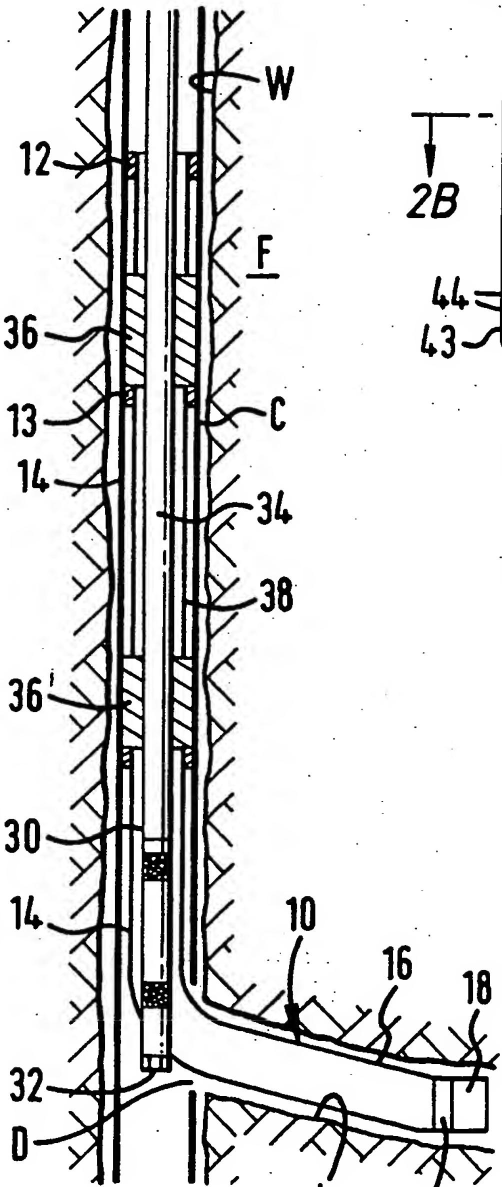

W
12
F
36
13
C
34
38
36
30
14
10
L
18
32
D
20

FIG. 1F



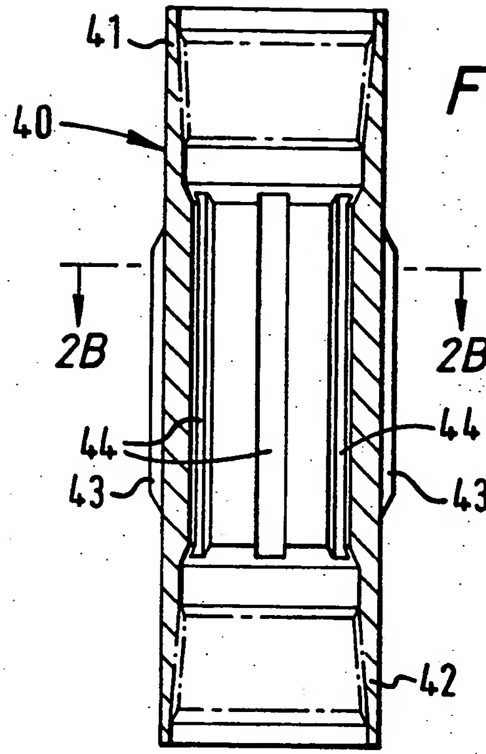


FIG. 2A

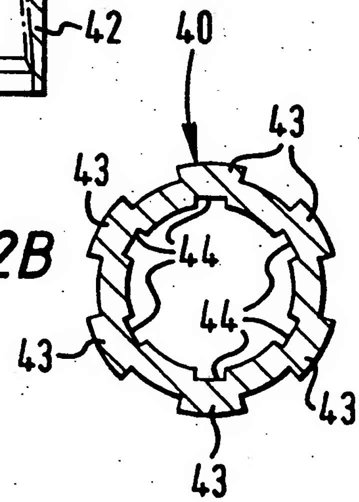


FIG. 2B

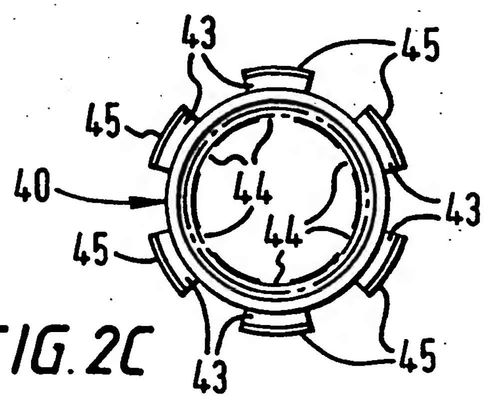


FIG. 2C

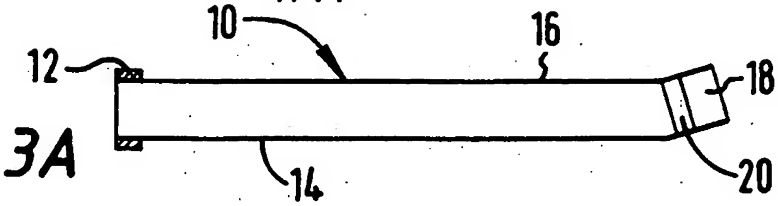


FIG. 3A

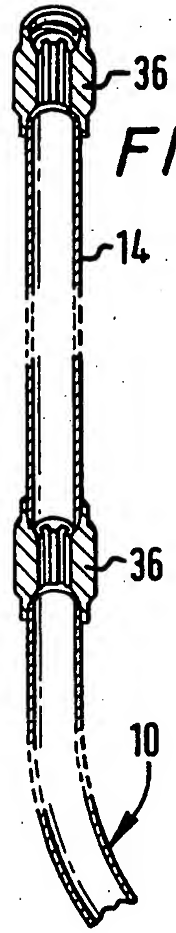


FIG. 3B

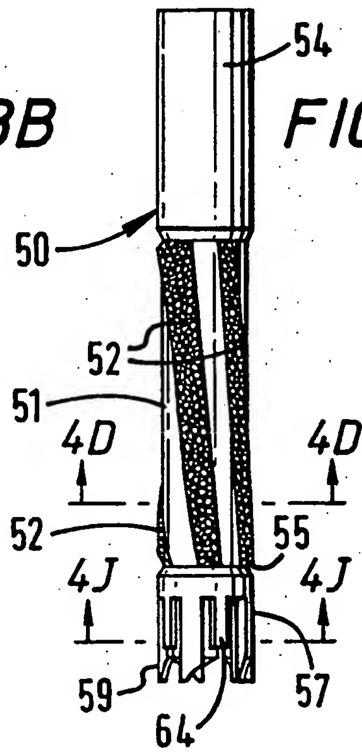


FIG. 4A

FIG. 4C

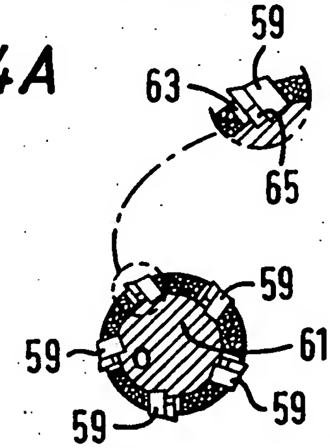


FIG. 4B

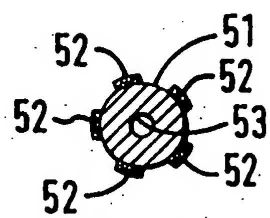


FIG. 4D

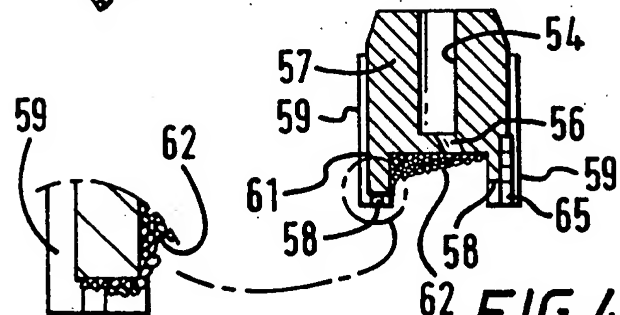


FIG. 4E

FIG. 4F

FIG. 4J

FIG. 4G

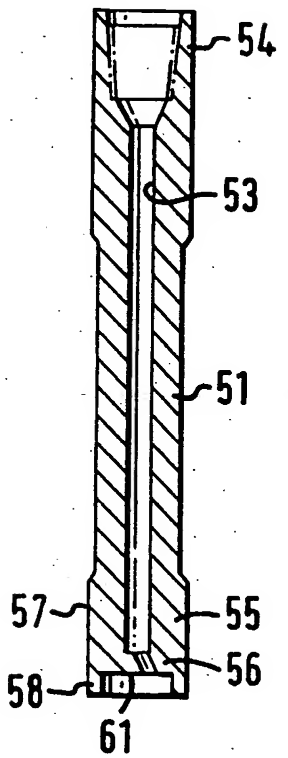


FIG. 5A

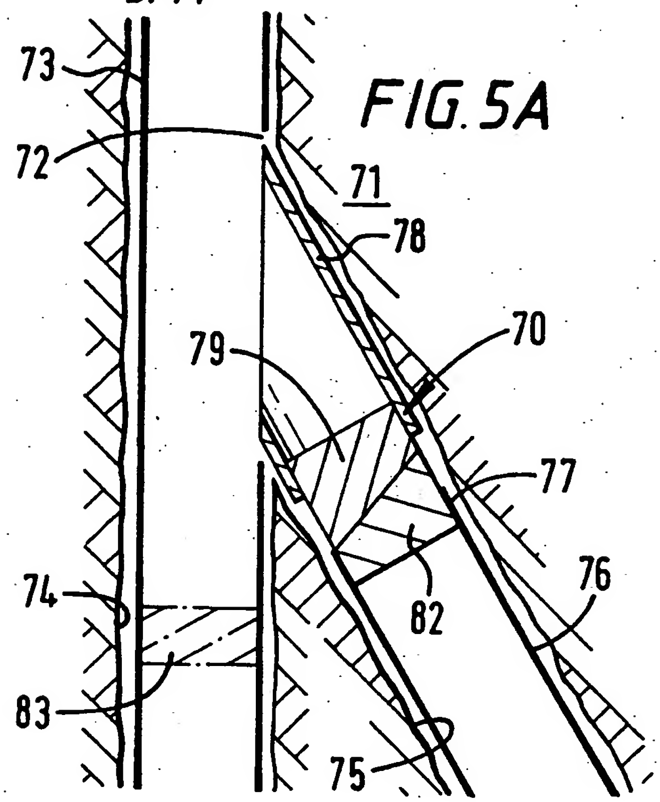


FIG. 4H

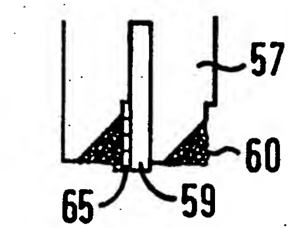


FIG. 5B

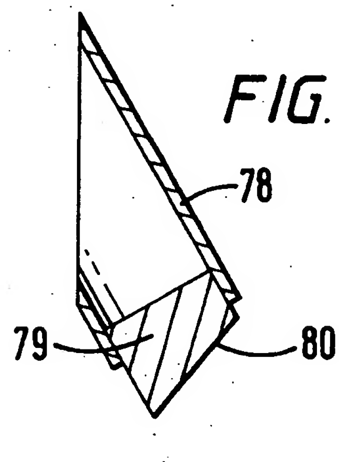
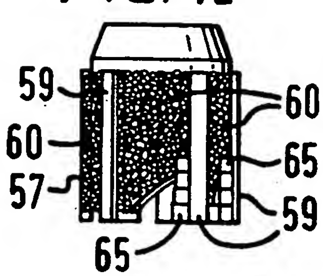


FIG. 4I



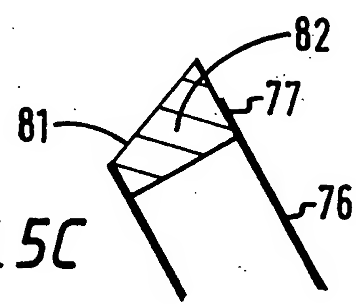


FIG. 5C

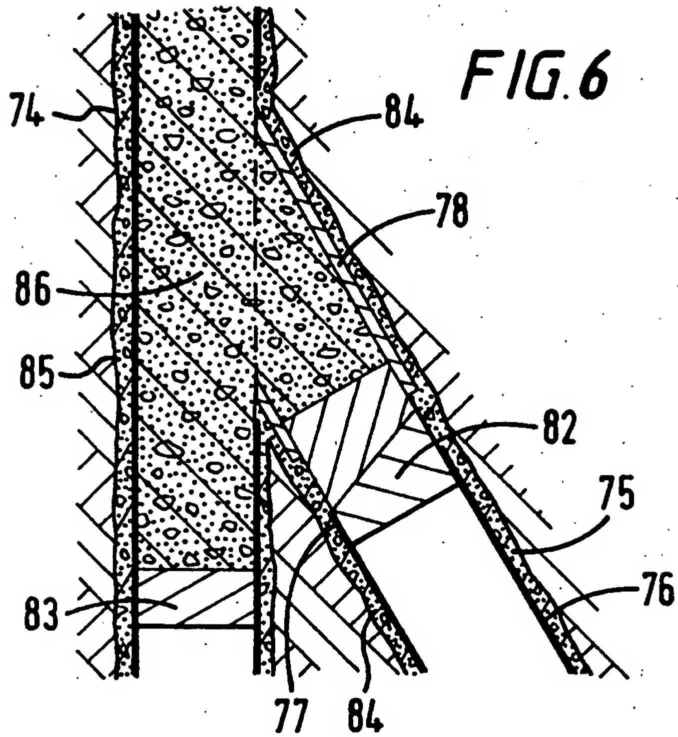


FIG.6

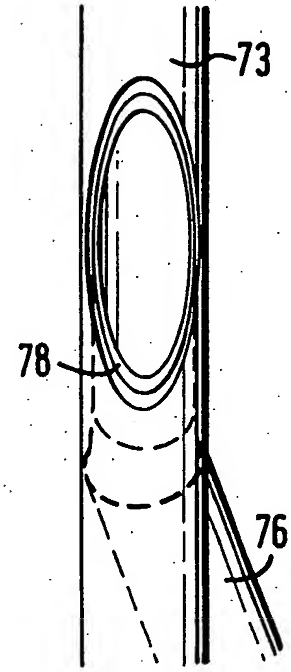


FIG.7

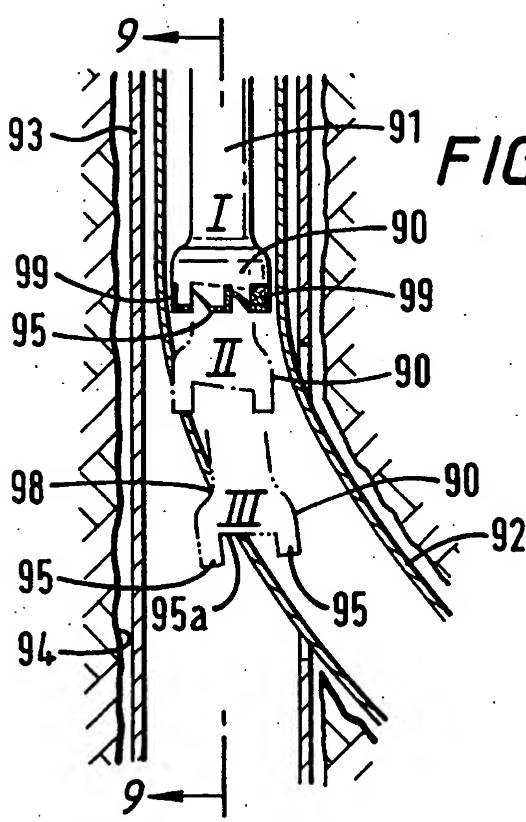


FIG.8

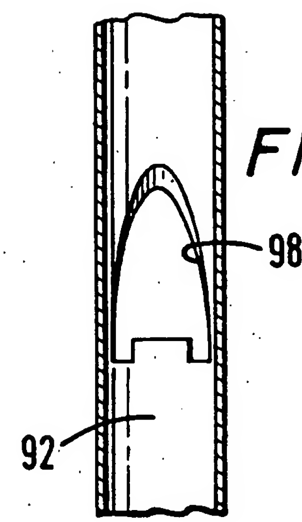


FIG.9

FIG. 10

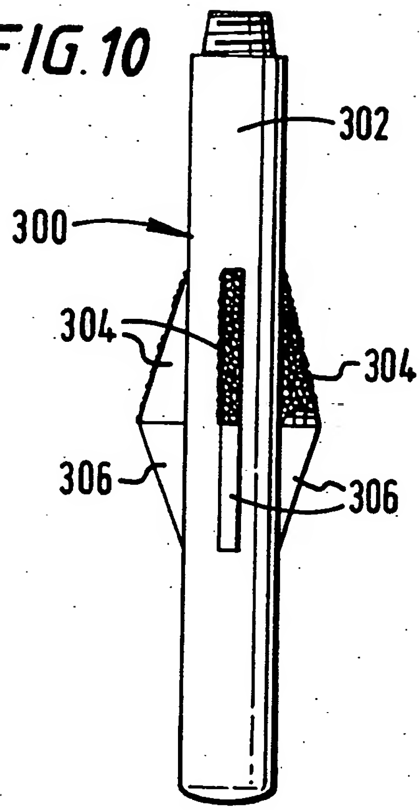


FIG. 11

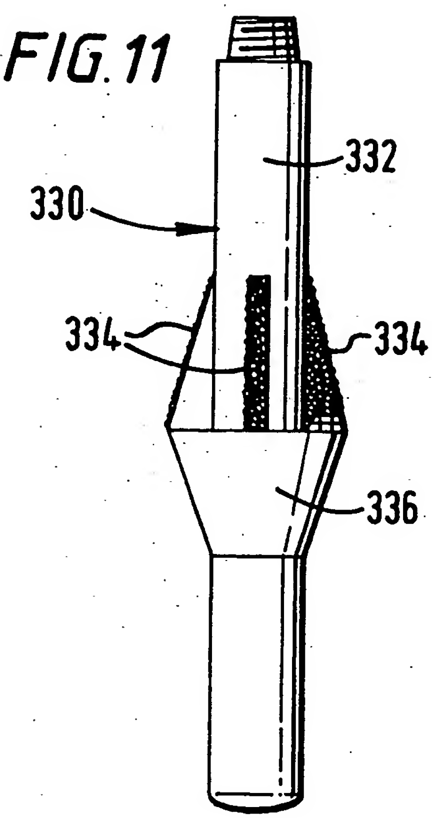


FIG. 12

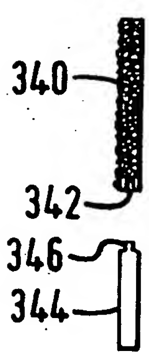


FIG. 13

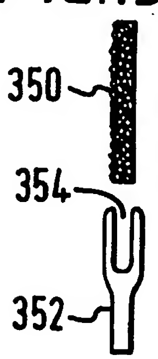


FIG. 14A

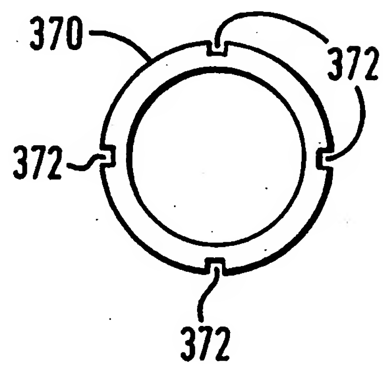


FIG. 14B

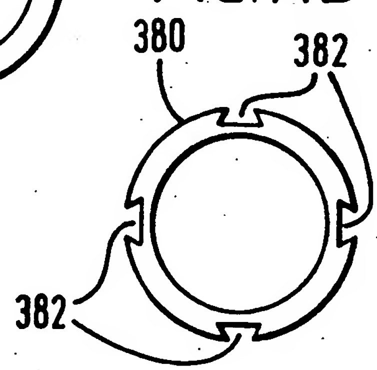


FIG. 15A

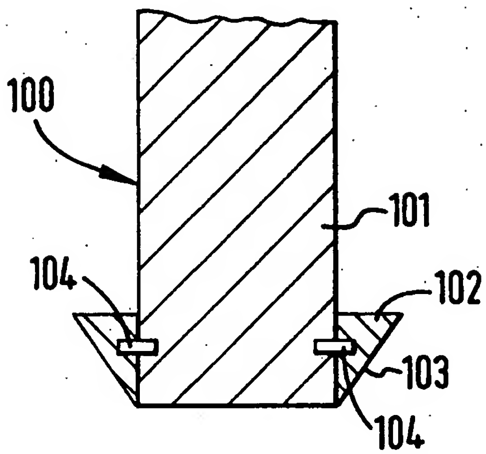


FIG. 15B

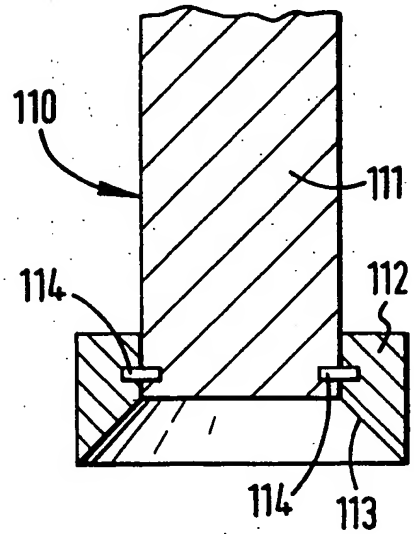


FIG. 15C

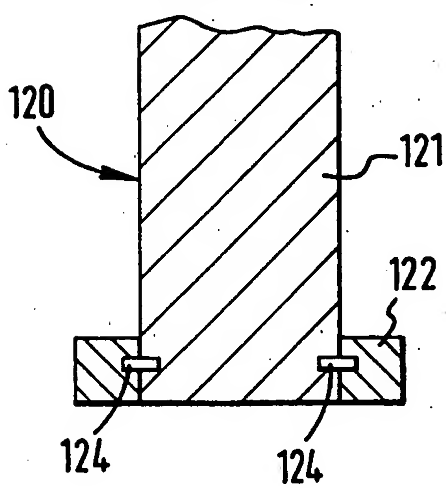
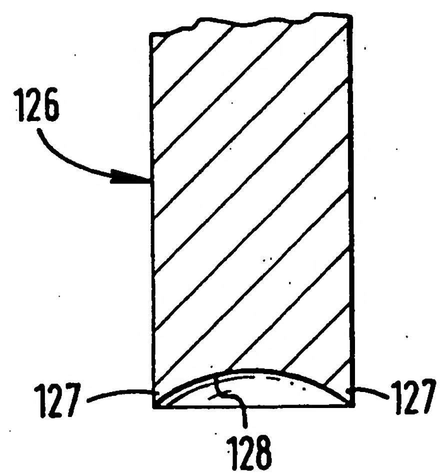


FIG. 15D



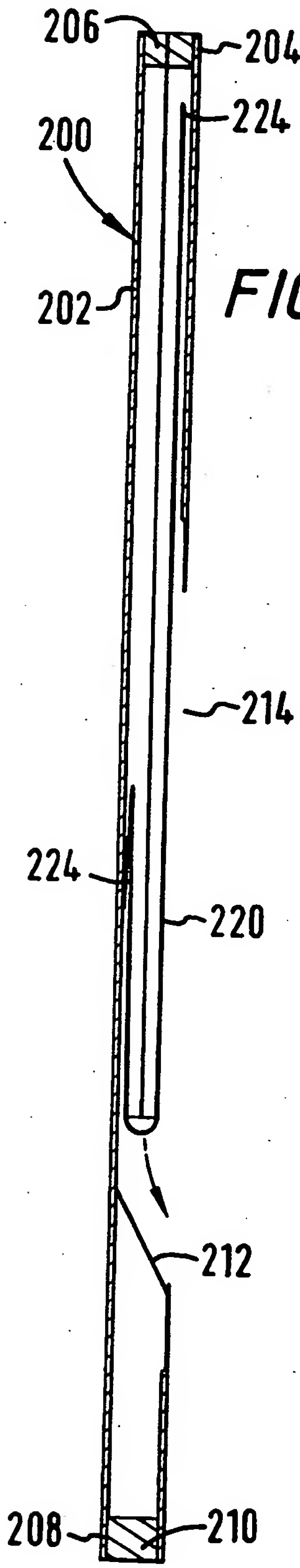


FIG.16A

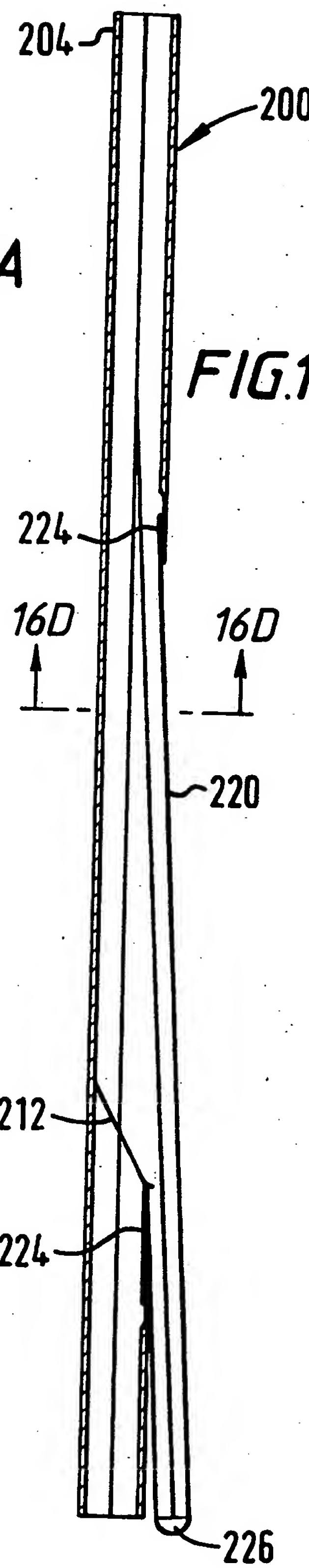


FIG.16B

FIG.16C

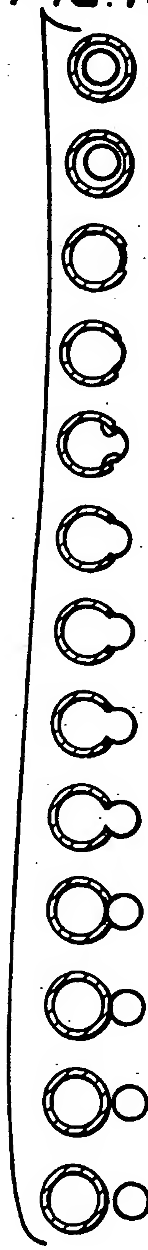


FIG.16D

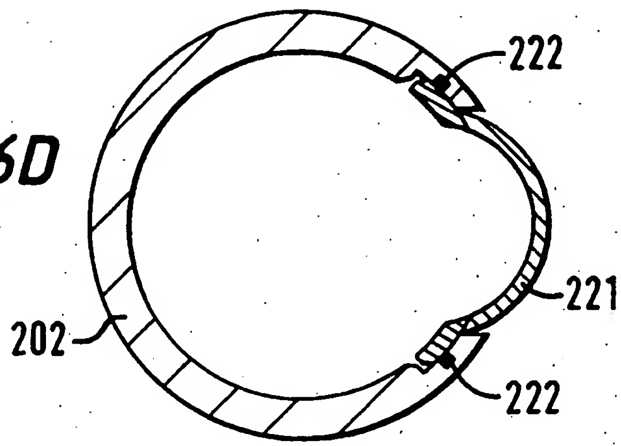
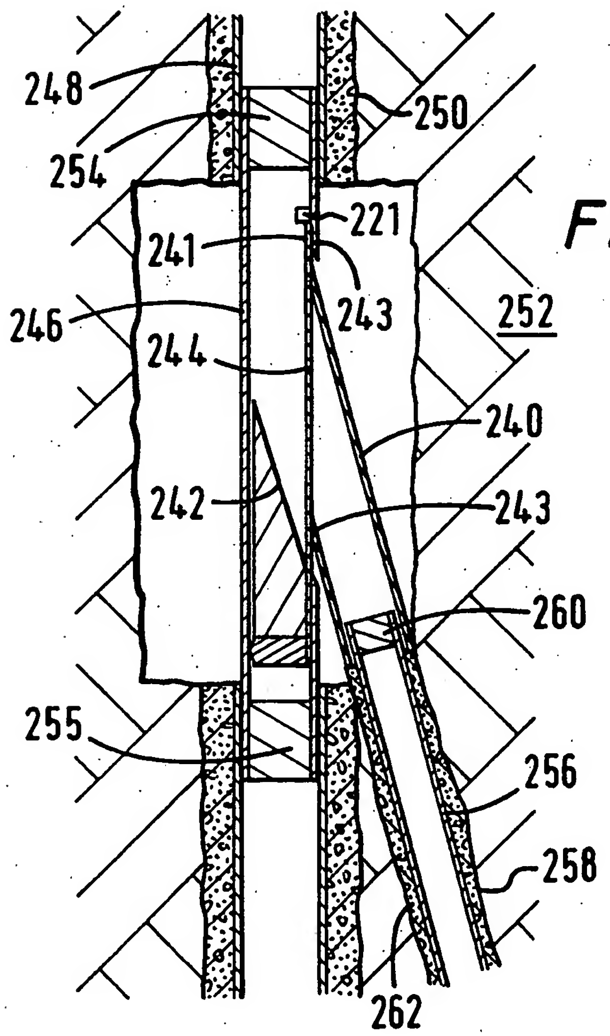


FIG.16E



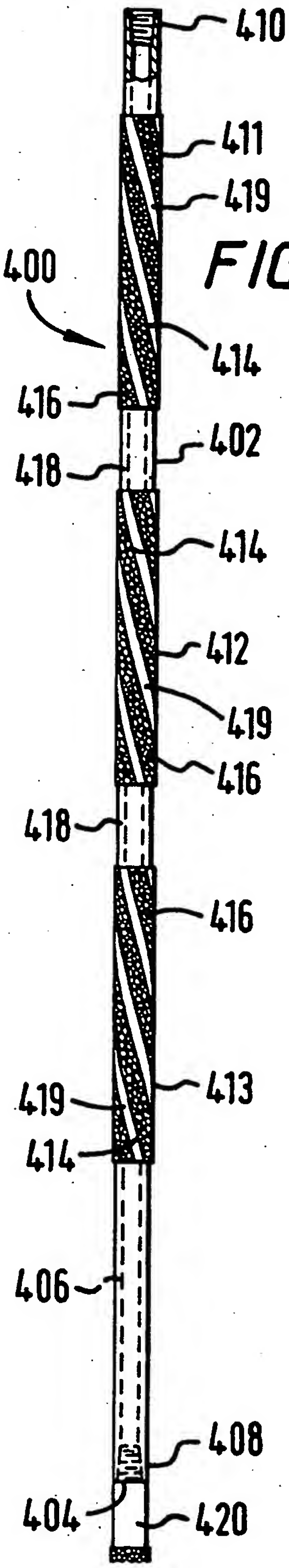


FIG. 17

FIG. 18A

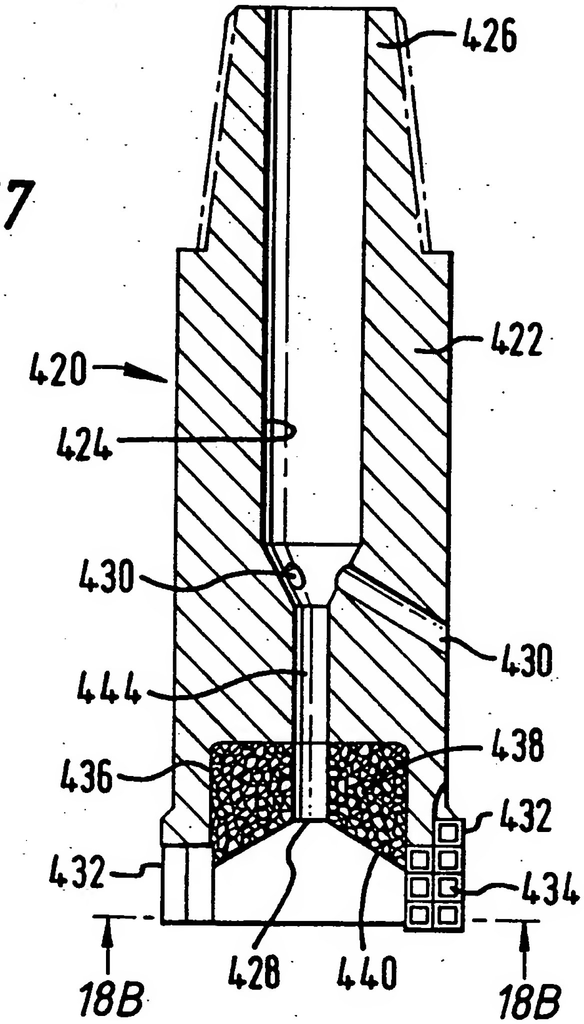


FIG. 18B

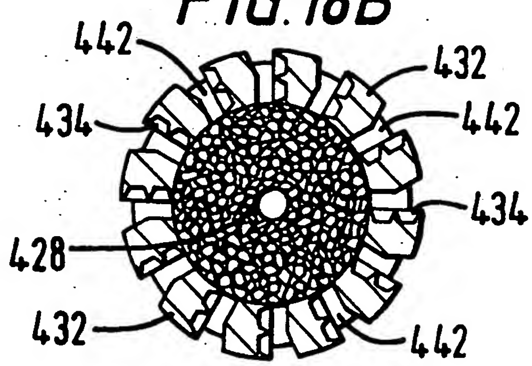
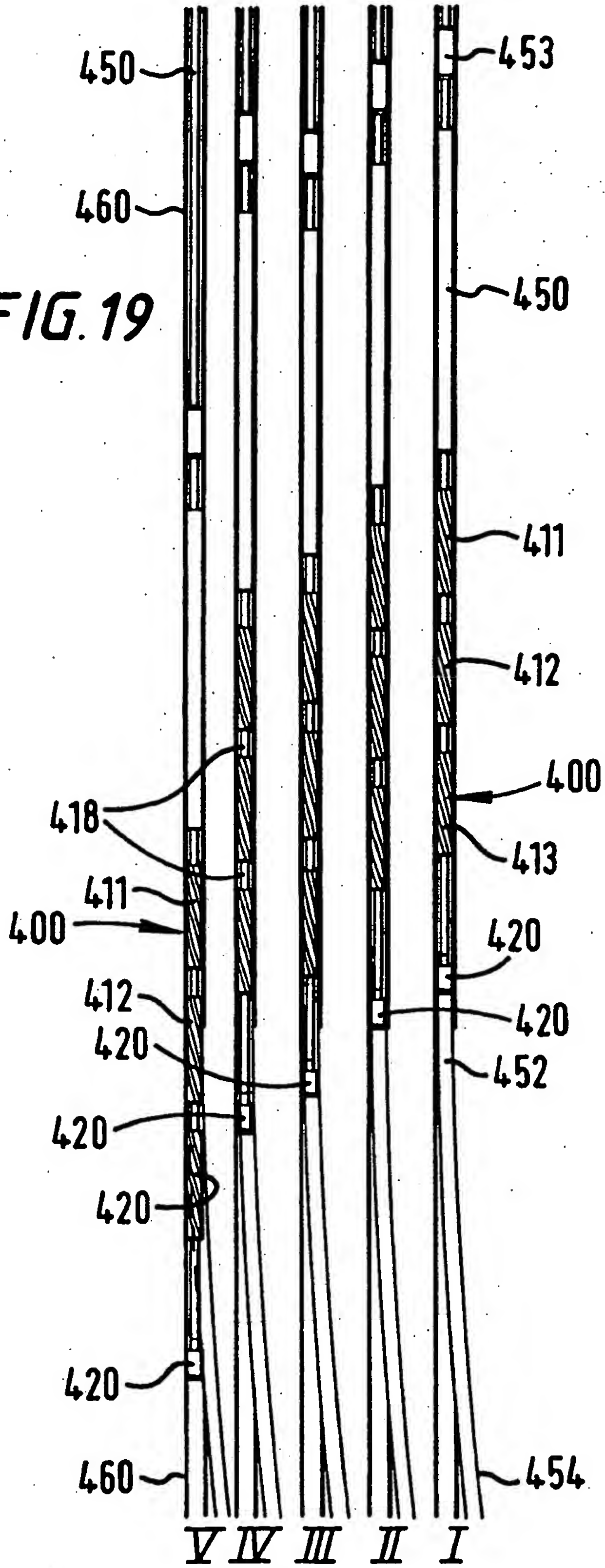


FIG. 19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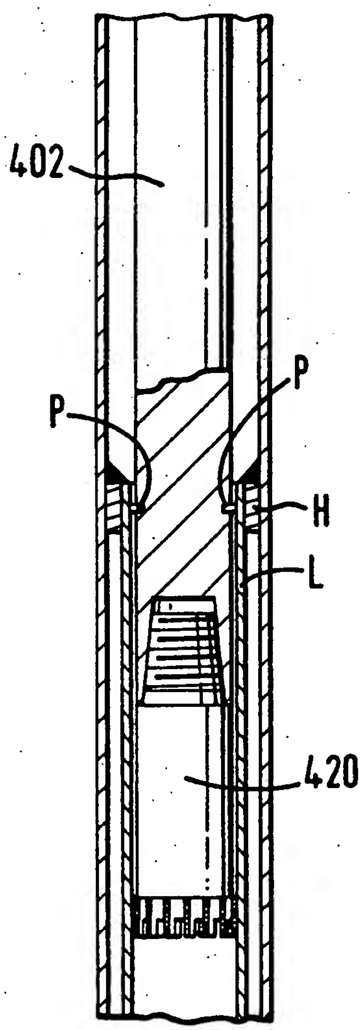
V
IV
III
II
I

FIG. 20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P
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L
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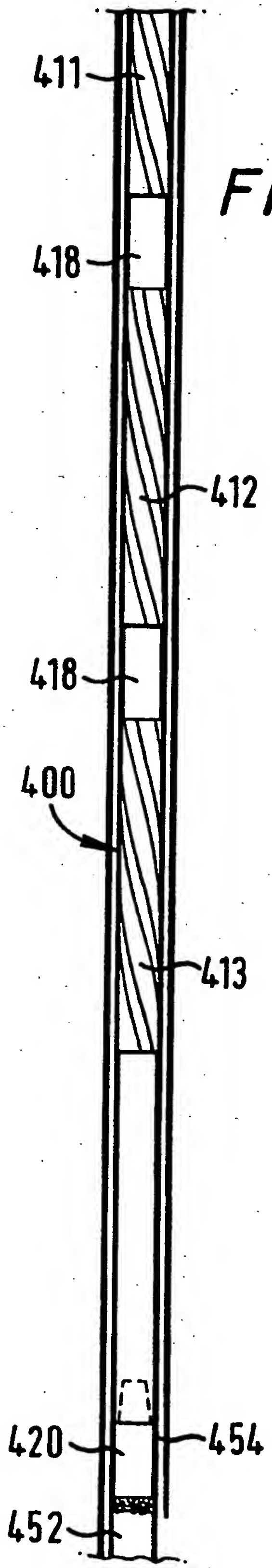


FIG.19A

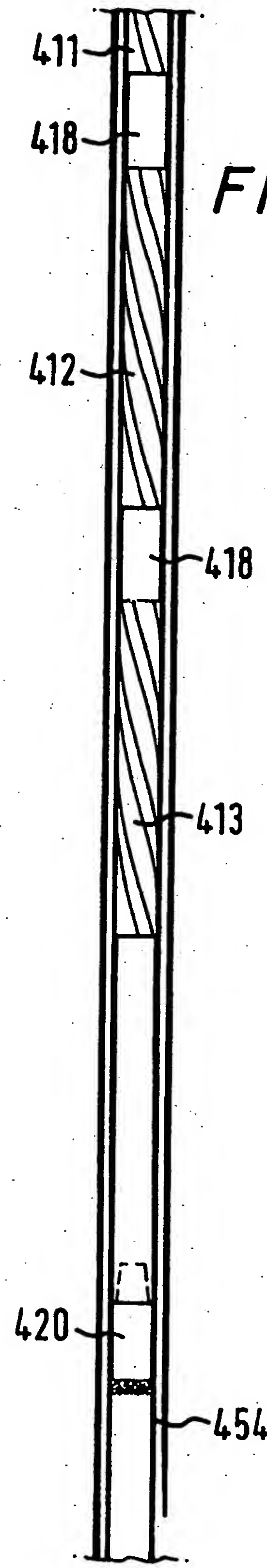


FIG.19B

FIG.19C

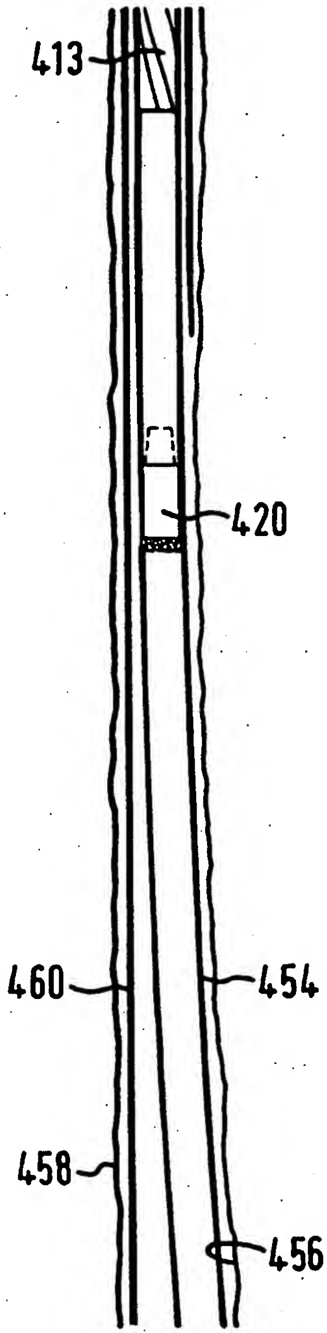


FIG.19D

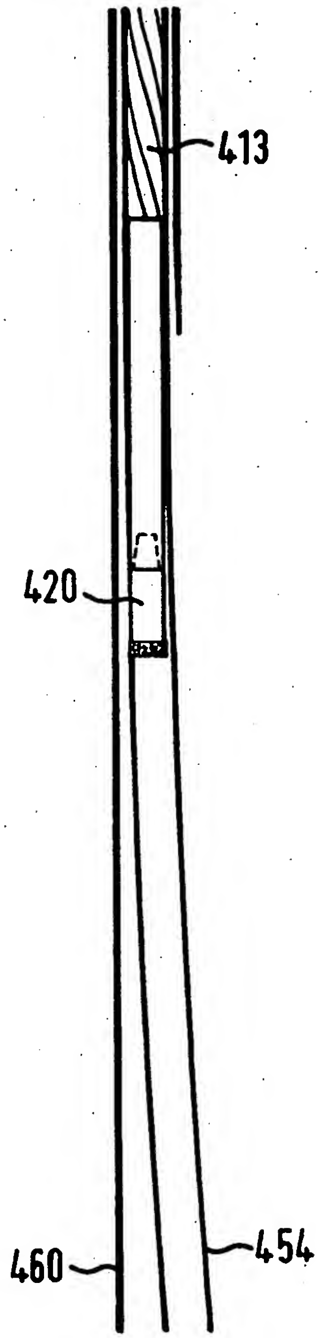
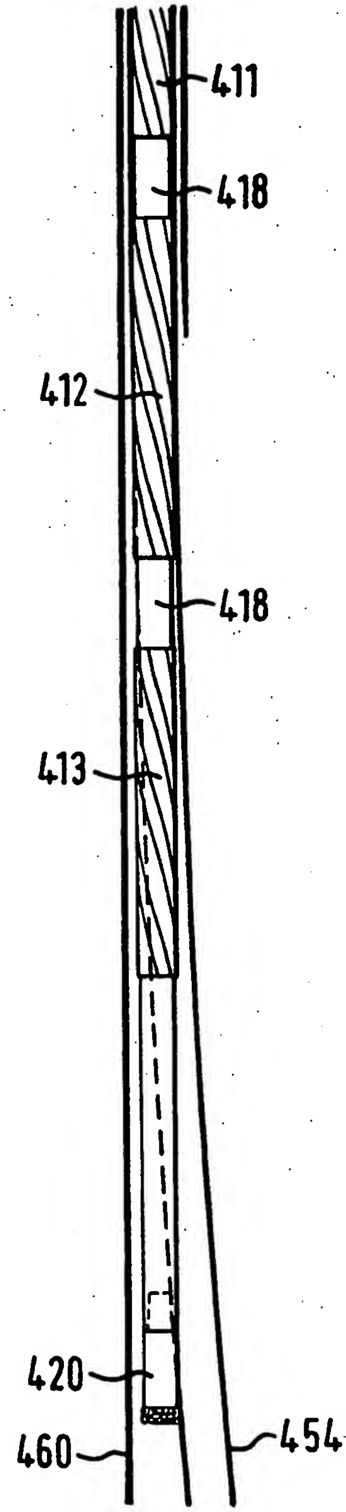


FIG.19E



INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 99/01028

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 E21B29/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2 303 159 A (BAKER HUGHES INC) 12 February 1997 see page 8, line 1-11 see figures 7-9	1
A	US 5 564 503 A (COX DON C ET AL) 15 October 1996 see column 19, line 56 - column 20, line 3 see figures 11,12	1
A	WO 94 03698 A (BAKER HUGHES INC) 17 February 1994 see page 21, line 23 - page 22, line 3 see figures 5G,H,I	1

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 June 1999	05/07/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Schouten, A

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INTERNATIONAL SEARCH REPORT

In ational Application No
PCT/GB 99/01028

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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A	"NEW TOOLS, TECHNIQUES REDUCE HIGH-ANGLE DRILLING COSTS" OFFSHORE, vol. 49, no. 11, 1 November 1989, pages 47-49, 52 - 54,, XP000068932 see page 47; figure 1 ---	1
A	GRAHAM S A ET AL: "SECOND LATERAL IN HORIZONTAL WELL SOLVES WATER PROBLEM" OIL AND GAS JOURNAL, vol. 89, no. 11, 18 March 1991, pages 111-114, XP000200909 see page 113; figure 5 -----	1

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PCT/GB 99/01028

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